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13. ABSTRACT ***(Maximum 200 words)***

The principal objective of this project is to investigate problems associated with achieving the drive/read-out system complexity necessary to control a phased array antenna with optical heterodyne techniques. In particular, this work has concentrated on multi-channel microwave optical conversion. The approach has been to study the problems associated with device arrays of single sideband modulators that would be necessary to control the amplitudes and phases of all signals delivered to a phased array front end. The incorporation of our available in-house developed tools into that of already existing tools (such as MDS-Microwave Design Software) has been undertaken to design a single side-band modulator (SSBM). It was found that MESFET oscillators and the associated control lasers can be modeled by simply changing a constant in the model to give their characteristics with and with out optical injection. This is useful for injection locking of active antenns for accurate and efficient phased array antenna design.

14. SUBJECT TERMS
microwave optics, phased array radar, modulation transfer function, injection locking, optical sampling

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FINAL PROGRESS REPORT

for Office of Naval Research
for the period August 1992 through January 1995

1. **Contract Title:**
An Investigation of the Channel Crosstalk in Optical Heterodyne Controlled Phased Array Radars

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Dr. Arthur Jordan

2. **Technical Objectives:**
The principal objective of this project is to investigate problems associated with achieving the drive/read-out system complexity necessary to control a phased array antenna with optical heterodyne techniques. In particular, this work concentrated on multi-channel microwave optical conversion.

3. **Approach:**
The approach has been to study the problems associated with device arrays of single sideband modulators that would be necessary to control the amplitudes and phases of all signals delivered to a phased array front end. Our approach has also focused on increasing the complexity of control by modulating only a small number of optical channels which can then be locked to a previously locked active antenna array. This approached has enabled a better understanding of the accuracy and validity of our computer aided analysis and also has allowed a greater range of device complexity to be analyzed.

4. **Accomplishments:**
The development of "ZOOM," a computer-aided electromagnetic analysis technique, was extended to allow analysis of more complicated electrode geometries. A greens function for electrodes on multiple dielectric layers was derived and incorporated into the program. This allows accurate modeling of realistic optical devices. Additionally, the incorporation of our available in-house developed tools into that of already existing tools (such as MDS-Microwave Design Software) has been undertaken to design a single side-band modulator (SSBM).

Potential distributions of an active antenna array (composed of a 5X5 array of oscillating field effect transistors) given by optical sampling measurements agree with theoretical calculations. These results show that the stability of the active device is determined by the near field radiation and electrode geometry within a period of an elementary cell. Additionally, it was found that the bias lines of the active array provide both the dc bias to the active device and provides a coplanar structure that supports a radiation mode.

The optical to microwave modulation transfer function has been derived for an optically injected FET (field effect transistor). The transfer function can then give the characteristics of the optically injected microwave MESFET oscillator circuit. The model can vary the injected

power level and the amount of phase detuning between the injected signal and the free running oscillation making it possible to accurately model microwave control by optical means.

5. Significance:

The significance of these accomplishments are threefold. First, the CAD tools for microwave devices has been a hierarchical one, much as hierarchical tools are the ones in use in the digital and microwave circuit design areas. Here, we have used MDS CAD for the design of the higher level simulations in the design of a SSBN. Secondly, the geometry of an active antenna plays an important role in its feasibility as an effective control for complicated drive/read- out phased array system. This will enable an efficient antenna array to be constructed. Electromagnetic analyses of a realistic stacked multilayer dielectric and its associated electrode structure makes it possible to design and model the required complexity needed for multi-channel microwave optical conversion. Finally, it was found that MESFET oscillators and the associated control lasers can be modeled by simply changing a constant in the model to give their characteristics with and with out optical injection.

6. Future Efforts:

Future work involves trying to physically understand locked array results while simultaneously trying to modify existent software to accurately analyze optically addressed antenna elements.

7. Publications and Presentations Partially Supported Under This Grant June 1, 1994 through February 28, 1995

S. L. Kwiatkowski and A. R. Mickelson, "Perturbations on Effective Index of Refraction from Prism Coupling," submitted to *Appl Optics.*

P. Biernacki, H. Lee, and A. Mickelson, "Evaluation of Defect Related Diffusion in Semiconductors by Electrooptical Sampling," submitted to *Appl Optics.*

S. L. Kwiatkowski, A. R. Mickelson, and D. R. Hjelme, "On-axis polarization coupling in y-cut titanium indiffused lithiumniobate slab waveguides," submitted to *Appl. Optics.*

A. R. Mickelson, "Rare Earth Integrated Optics," International Union of Radio Science, Boulder (CO), (Jan. 3-6, 1995).

A. R. Mickelson, "Rare Earth Doped Polymers," International Union of Radio Science, Boulder (CO), (Jan. 3-6, 1995).

J. Ma and A. R. Mickelson, "Optical Interconnects in VLSI Systems Using Polymer Waveguides and Switches," International Union of Radio Science, Boulder (CO), (Jan. 3-6, 1995).

R. Narayan and A.R. Mickelson, "Channel Waveguide Studies in Mg-Doped LiNbO3," International Union of Radio Science, Boulder (CO), (Jan. 3-6, 1995).

P. Biernacki, H. Lee and A.R. Mickelson, "Optical Sampling for Determination of Material Characteristics," International Union of Radio Science, Boulder (CO), (Jan. 3-6, 1995).

S. Lin and A. R. Mickelson, "Nd-Chelate-Doped Polymer Waveguides for Optical Amplifiers," International Union of Radio Science, Boulder (CO), (Jan. 3-6, 1995).

D. Tomic, S. Lin, W. Feng, and A. R. Mickelson, "What Limits Passive Directional Coupler Crosstalk," International Union of Radio Science, Boulder (CO), (Jan. 3-6, 1995).

W. Feng, R. B. Hooker and A. R. Mickelson, "Polymeric Electrooptic Devices," International Union of Radio Science, Boulder (CO), (Jan. 3-6, 1995).

P. Biernacki, K.Y. Cheng, D.R. Hjelme and A.R. Mickelson, 1994. "Determination of Electrode Currents from Electro-optical Sampling Measurements," in Defect Recognition and Image Processing in Semiconductors and Devices, ed. J. Jimenez, Institute of Physics Conference Series Number 135, (1994).

P. Biernacki, D.R. Hjelme, M. Yadlowsky, A.R. Mickelson, "Electro-Optical Sampling for High Frequency Electric Circuits," in Defect Recognition and Image Processing in Semiconductors and Devices, ed. J. Jimenez, Institute of Physics Conference Series Number 135, (1994).

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R. Narayan and A. R. Mickelson, "Characterization of Mg-doped Lithium Niobate," International Workshop on Ferroelectric Integrated Optics, Breckenridge (CO), August 17-19, (1994).

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A. R. Mickelson, "Heterodyne Phased Array," Workshop on Optically Controlled Phased Array Antenna Systems for Military Communications-on-the-Move, CECOM, Fort Monmouth (NJ), July 6, (1994).

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S.J. Buchheit and A.R. Mickelson, "Electromagnetic Modeling of Active Circuits," International Union of Radio Science, Boulder (CO), (Jan. 5-8, 1994).

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M. Popovic, S.L. Kwiatkowski, and A.R. Mickelson, "Characterization of X-Cut LiNbO3 Planar Waveguides," International Union of Radio Science, Boulder (CO), (Jan. 5-8, 1994).

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L.E. Primas, V. Jevremovic, A.R. Mickelson, and Z. Popovic, "Microwave Characterization of Polymeric Materials for Electro-Optic Devices," National Radio Science Meeting, URSI, Boulder (January 1993).

S.M. Genco, J. Buetow, Z. Popovic, and A. Mickelson, "Enhanced SNR and Stability of Microwave MESFET Oscillators via Optically Injected Signals," National Radio Science Meeting, URSI, Boulder (January 1993).

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P.J. Matthews and A.R. Mickelson., "Instabilities in Annealed Proton Exchange Waveguides in Lithium Tantalate, "*Journ. Applied Phisics*, 71 pp. 5310-5317, (Nov. 1992)

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Theses During Project:

L. Rohlev, Ph.D., "Characterization of Optical Polymers for Multilayered Electrooptic Devices."

S. Genco, Ph.D., "Characterization of Microwave MESFET Circuits under Laser Illumination: Applications to Phased Array Radar, Microwave Communications, and Digital Clock Control."

K. Chen, Ph.D., "Active Antennas with Periodic Structures."

8. Participants:

Professor Alan R. Mickelson
Kuang Yi Chen
Raghu Narayan
Sheryl Genco
Lori Rohlev